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On the Size and Composition of Particles in Polar Stratospheric Clouds

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Attenuation measurements of the solar radiation between 1.5 and 15 µm wavelenghts were performed with the airborne (DC-8) JPL MARK IV interferometer during the 1987 Antarctic Expedition. The opacities not only provide information about the abundance of stratospheric gases but also about the optical depths of polar stratospheric clouds (PSCs) at wavelengths of negligible gas absorption (windows).

The optical depth τ of PSCs can be determined for each window once the background attenuation, due to air-molecules and aerosol has been filtered out with the simple extinction law (the 'λ' subscript is used to indicate the wavelength dependency) :

$$\frac{I_{PSC,\lambda}}{I_{B,\lambda}} = \frac{I_{o,\lambda}\, F_\lambda \exp -[(\tau_{PSC,\lambda} + \tau_{B,\lambda})\,/\mu]}{I_{o,\lambda}\, F_\lambda \exp -[\tau_{B,\lambda}\,/\mu]} = \exp\ -[\tau_{PSC,\lambda}\,/\mu]$$

where I_{PSC}, I_B and I_o represent measured attenuations of solar radiation for clouds, background aerosols and clear conditions, respectively. F is an instrument function and μ is the cosine of the almost horizontal solar zenith angle (83 to 89 degrees).

The ratio of optical thicknesses at different wavelengths reveals information about particle size and particle composition. Figure 1 shows the calculated extinction ratios for six different log-normal particle size distributions. Small particles rapidly loose their ability to attenuate at large wavelengths, while the attenuation of large particles has almost no spectral dependency. Figure 2 displays calculated extinction ratios for ice and water particles for one log-normal particle size distribution. Their difference is depicted by the shaded area. Sampling in PSCs has shown that sub-micron particles carry nitric acid. Thus, values for four nitric acid solution of different concentrations are graphed in Figure 2 as well. The behavior of the extinction ratios is so different, that the concentration of nitric acid in sub micron size cloud particles may be detected.

Among the almost 700 measured spectra only a few PSC cases exist. PSC events are identified by sudden reductions in the spectrally integrated intensity value and are also verified with backscttering data from an upward directed lidar instrument, that was mounted on the DC-8. For the selected case on September 21st at 14.40 GMT, lidar data indicate an optically thin cloud at 18km and later an additional optically thick cloud at 15km altitude.

Equivalent vertical optical depths were calculated based on the cosine dependence of the solar zenith angle and are presented in Figures 3 and 4 for both cloud types. The cosine assumption, however, overestimates optical paths for solar zenith angles in excess of 85^{0}. Since the selected cases are associated with an angle of 88^{0}, actual vertical optical depths are about twice of that indicated in Figures 3 and 4.

A comparison with Figures 1 and 2 reveals for the high cloud a typical particle radius of about 0.5µm and a high nitric acid concentration, based in particular on the extinction behavior at 3µm wavelength. The low cloud in contrast displays particle sizes in excess of 5µm radius. Their relative large ice water content makes high nitric acid concentration unlikely.

Many more PSC measurements were analyzed. Their spectral extinction dependencies reveal particles heavily varying in size and composition. The similarity of most cases to either that of Figure 3 or 4, however, suggests a particle classification.

All results still suffer from (1) often arbitrary definitions of a 'clear' case, that often already may have contained PSC particles and (2) noise problems that restrict the calculations of optical depths to values larger than 0.001. Once these problems are handled, this instrument may become a valuable tool towards a better understanding of the role PSCs play in the antarctic stratosphere.

Figure Captions

Fig. 1 Illustrated are extinction ratios of log-normal particle size distributions for mean particle radii of .125, .25, .5, 1, 2 and 4µm. (s - shape factor, RI - Refractive Index [constant]).

Fig. 2 Illustrated are extinction ratios of 0.5µm log-normal particle size distributions for ICE, WATER and several NITRIC ACID solutions.

Fig. 3 Illustrated are cosinus corrected vertical optical depths for a high PSC-cloud at 18Km altitude.

Fig. 4 Illustrated are cosinus corrected vertical optical depths for a PSC-cloud at 15km altitude.

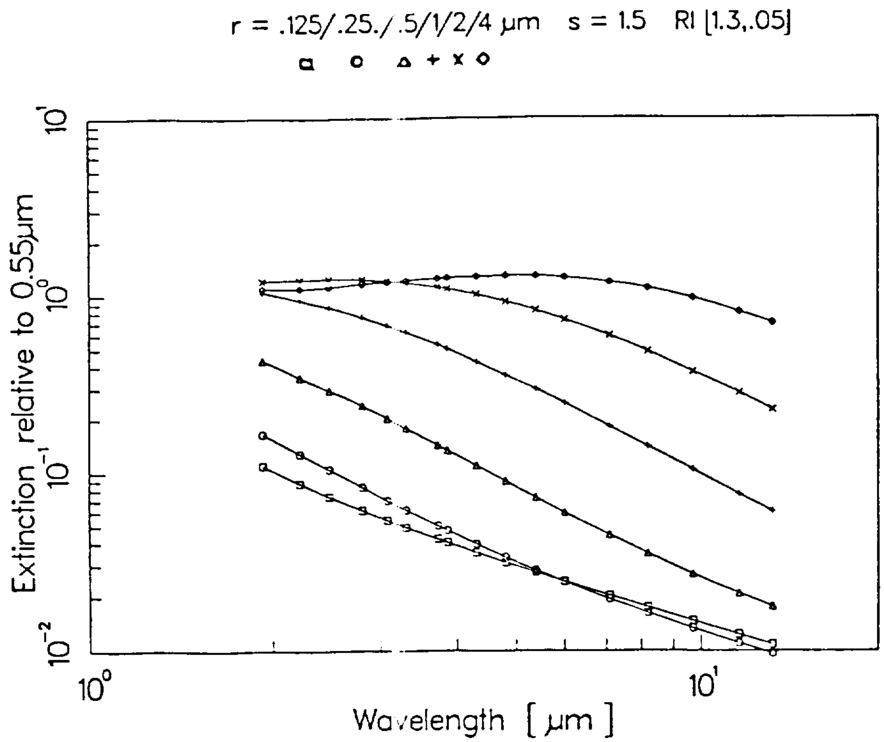

Figure 1

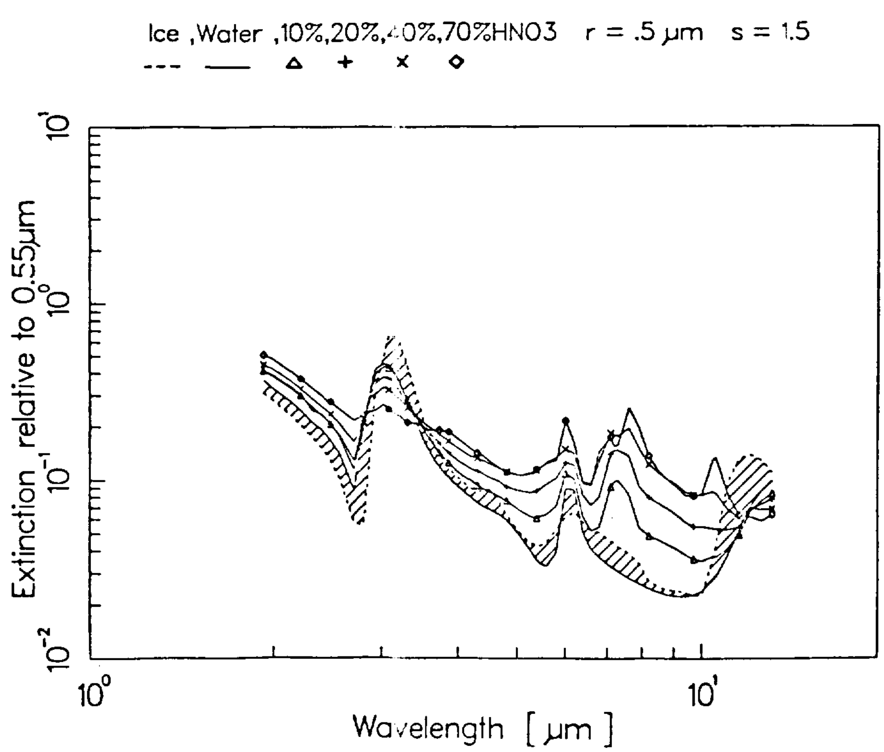

Figure 2

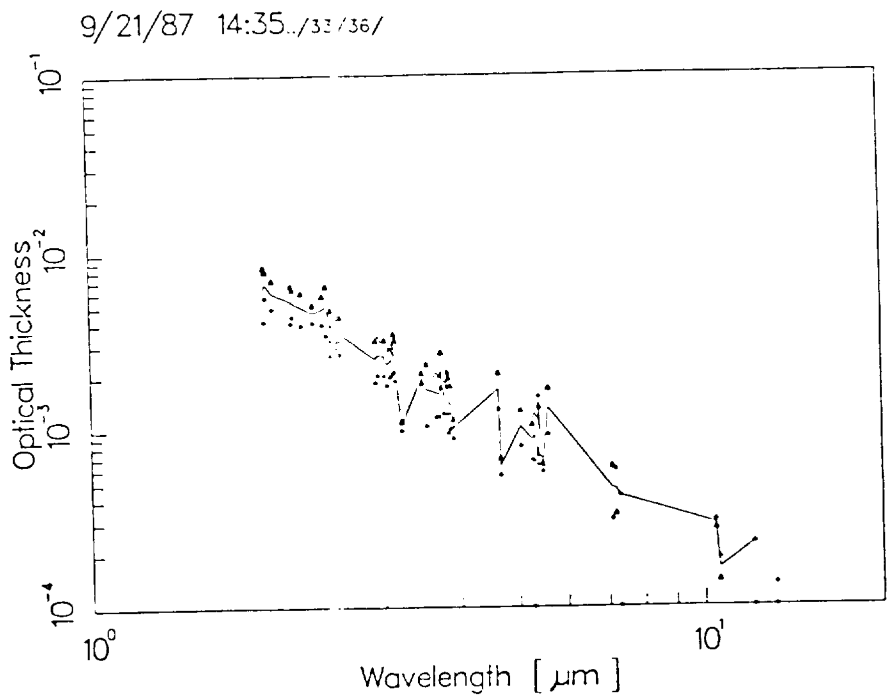

Figure 3

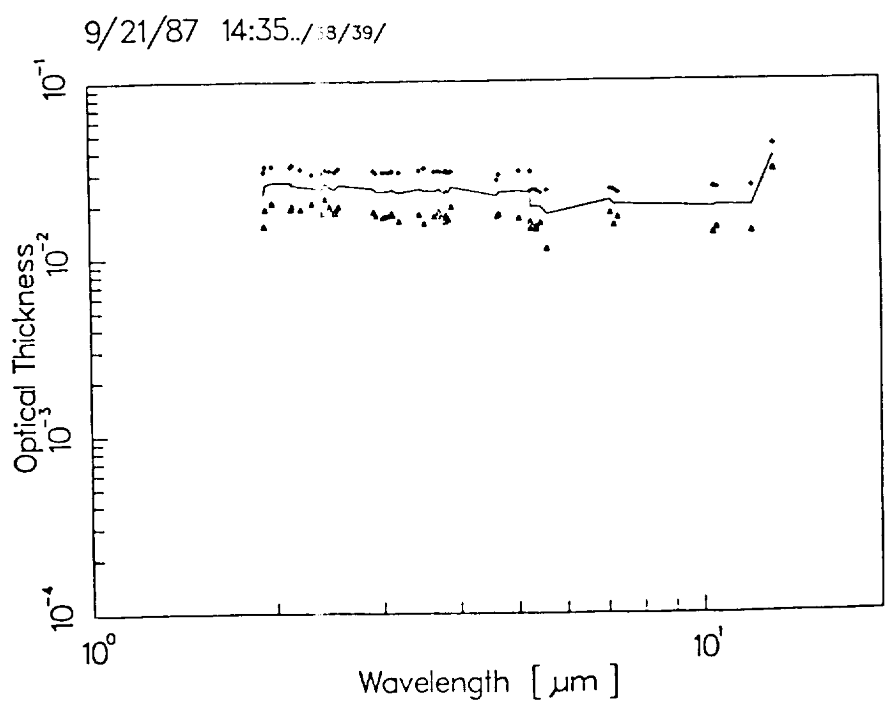

Figure 4